



**Asia-Pacific
Economic Cooperation**

**APEC Workshop on Renewable Energy Grid
Integration Systems**

Workshop Summary

Energy Working Group

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Introduction

Power output from certain renewable energy sources, like wind and solar, can be intermittent. Fluctuations in output can negatively affect power grid frequencies, voltages and component performance, causing instability in the power generation system and interrupted service to customers. Concerns about power system reliability limit the amount of new and renewable energy that power utilities and transmission system operators allow to be connected to the grid.

Renewable energy technologies are vital to helping the Asia-Pacific Economic Cooperation (APEC) region meet its growing electric power needs in a cost-effective and environmentally sustainable fashion. The deployment of renewable and distributed energy systems will likely accelerate in coming years to meet increased demand.

Recent analyses of modeling and simulation tools indicate that a greater share of renewable energy sources may be economically feasible and technically sound for grid integration. Grid operation and management techniques have also shown marked improvement. Lastly, energy storage technologies costs have been reduced significantly.

The United States Department of Energy (US DOE) sponsored the Asia Pacific Economic Cooperation Renewable Energy Grid Integration Systems (REGIS) Workshop at the Four Seasons Resort in Lanai, Hawaii from January 12-15, 2009. The objective of the workshop was to build consensus on the practical steps required for APEC economies to implement and expand grid-connected renewable energy technology options throughout the region. The workshop brought together power utility representatives, policymakers, renewable energy technology experts, industry regulators, electrical standards and codes reviewers, equipment suppliers, and transmission and distribution engineers to discuss the extent to which renewable energy sources can be integrated in the electric power grids of APEC economies.

The DOE-APEC REGIS workshop maintained a comprehensive format: opening plenary, technical presentations and discussions, and a site tour. The opening plenary covered projects and programs for which current and potential work could link to the workshop. The workshop covered topics on grid integration of wind and solar energy, energy storage, grid operation and management, modeling and simulation, renewable energy grids over time, and collaboration on renewable energy grid issues. The tour entailed a visit to the newly completed La Ola Solar Farm on Lanai and was restricted to workshop attendees. The workshop agenda can be found at the end of this report. Workshop presentations are available at: www.sandia.gov/regis.

Opening Plenary

The presenters gave an overview of their projects and programs and how this workshop could link into those projects and programs.

Asia-Pacific Economic Cooperation¹

APEC was created in 1989 to promote trade liberalization, trade facilitation and technical assistance. APEC economies account for more than one-third of the world's population, 60% of the world GNP, and 50% of world trade. APEC implements its activities through 11 working groups including the Energy Working Group (EWG). APEC funds about \$8 million per year for projects across all working groups. In 2008, 120 projects were submitted for APEC support, of which 32 were from the Energy Working Group. Proposals are funded through one of three mechanisms: the APEC Operational Account (the most general fund used to address APEC priorities), the APEC Support Fund (Directed at capacity building for the development of APEC economies), and the APEC Trade Investment and Liberalization Fund or TILF (funded by Japan, and directed at projects related to trade, such as equipment standards).

Three potential next steps were advanced to establish a link between APEC and the workshop. One link involves the Japanese-led APEC Expert Group on New and Renewable Energy Technologies (EGNRET) project, "Addressing Grid-interconnection Issues in Order to Maximize the Utilization of New and Renewable Energy Sources" (EWG 02/2009). Another potential link would be with a Chinese Taipei project called "APEC 21st Century Renewable Energy Development Initiative (Collaborative VI): APEC PV Collaborative Mechanism Study and Workshop," also being conducted through the APEC EGNRET. Lastly, an additional project based on the grid/renewables workshop conclusions could be proposed through EGNRET for APEC funding consideration.

New Energy and Industrial Technology Development Organization (NEDO)²

Founded in 1980 in response to the oil shocks, NEDO has become Japan's largest public management organization promoting the research and development and dissemination of new energy, energy efficiency, environmental and industrial technologies. With a budget of approximately \$2.3 billion and 1,000 personnel, NEDO promotes a collaborative research approach between the public, private and academic sectors.

Through its research and development efforts, NEDO seeks technical solutions for energy and environmental problems. NEDO has conducted many projects related to the development of photovoltaic and peripheral technologies over the past 28 years. To encourage sustainable development, NEDO conducts international model projects that introduce and ultimately disseminate advanced Japanese technologies in developing countries in the Asia-Pacific region. In the field of new and renewable energy, NEDO has implemented a total of 21 International Cooperative Demonstrative Projects Utilizing Photovoltaic Power Generation Systems. Many of

1. *APEC Energy Overview*, presented by Dr. Cary Bloyd, Center for Energy, Environmental, and Economic Systems Analysis (CEEESA), Decision and Information Sciences Division, Argonne National Laboratory, Illinois, USA, bloyd@anl.gov.

2. *Overview of the New Energy and Industrial Technology Development Organization (NEDO)*, presented by Ken Johnson, Deputy Director, International Projects Management Division, New Energy and Industrial Technology Development Organization, k-johnson@nedo.go.jp.

these projects seek to address issues that arise when variable power output from renewable energy resources are connected to grid systems.

With the encouragement of Japan's Ministry of Economy, Trade and Industry (METI), NEDO represents Japan at the APEC Expert Group on New and Renewable Energy Technology (EGNRET) meetings. In this capacity, and on behalf of Japan, NEDO proposed an APEC project entitled, "Addressing Grid-interconnection Issues in Order to Maximize the Utilization of New and Renewable Energy Sources." This project, which was approved in November 2008, will be carried out between May 2009 and December 2010, and will incorporate the results of the US DOE sponsored REGIS workshop.

US Department of Energy Solar Energy Grid Integration Systems Program³

The "Solar Energy Grid Integration Systems" (SEGIS) program is a subprogram of the Solar Energy Technologies Program (SETP) at the Office of Energy Efficiency, Renewable Energy, US Department of Energy (US DOE).⁴ SEGIS is a "systems" development program focused on new requirements for interconnecting PV into the electrical grid. SEGIS includes the intelligent hardware that strengthens the ties of smart grids, microgrids, PV, and other distributed generation systems. The US DOE investment spans three years (FY08-10) and is up to \$24 million (or \$40 million total including industry cost share) for three development stages: stage 1—9-month feasibility study, stage 2—1-year engineering development/prototyping, and stage 3—1-year toward commercialization.

Twelve SEGIS contractors were awarded funds in June 2008 (\$238,000 DOE funding per award) for Stage 1. The purpose of Stage 1 is to address solar energy integration application needs for smart grids, microgrids, demand response, zero-energy homes/buildings, communication portals, and plug-in hybrid electric vehicle (PHEV) integration. PHEVs are important to this program because it also focuses on energy storage to address integration of energy storage with high-penetration PV systems for residential, small commercial and commercial applications.

There are two funding opportunities for FY09. Opportunity 1 is for system level demonstration to analyze and display the effects of high-penetration PV systems on varying designs and operations of distribution circuits. Future solicitation topic areas will be derived from high-penetration workshop findings on high-priority RD&D activities and performance requirements for the defined high-penetration PV scenarios. The solicitation is targeted for release in May 2009 with awards to be made by September 2009. A total of \$2.6 million will be awarded in FY09, and \$2 million or more for FY10 and FY11. Opportunity 2 is for energy storage R&D for SEGIS-energy storage applications in the residential, small commercial and commercial sectors. The R&D plan will be developed in May 2009 to define energy storage R&D gap areas and their performance requirements for distributed PV integration applications, and to define codes and

3. *Solar Energy Grid Integration Systems "SEGIS" Program*, presented by Dan Ton, Systems Integration Team Lead, Solar Energy Technologies Program, US Department of Energy, dan.ton@ee.doe.gov.

4. For DOE Solar Energy Technologies Program, see www1.eere.energy.gov/solar/
For the System Integration, see www1.eere.energy.gov/solar/systems_integration_program.html.

standards governing SEGIS-energy storage applications. A solicitation to address selected high-priority R&D areas is targeted for release in June 2009, with awards to be made by September 2009. US DOE funding is set at \$550,000-750,000 for FY09.

Hawaii Clean Energy Initiative⁵

Hawaii is dependent on oil for nearly all of its energy production. As more than 96% of petroleum in the state now comes from foreign sources (not from Alaska North Slope), Hawaii is even more vulnerable and subject to foreign political instability. From October 2007 to July 2008, oil prices increased from \$88 to nearly \$147 per barrel. According to the Honolulu Consumer Price Index (CPI), household fuel and utility costs rose 36.4% during the second quarter of 2008. While mainland energy costs are typically 4% of a state's gross domestic product (GDP), in Hawaii, it approaches 11%--almost three times higher. Between 2007 and 2008, State Government electricity usage decreased 1.17% but expenditures increased 19.55%.

The Hawaii Clean Energy Initiative (HCEI) consists of an agreement between the state and US DOE. HCEI's goals are to achieve a 70% clean energy economy for Hawaii within a generation, to increase Hawaii's energy security, to capture the economic benefits of clean energy for all levels of society, to foster and demonstrate innovation, to build the workforce of the future, and to serve as a model for the US and the world.

The transition from imported oil to a clean energy economy requires transforming regulatory, financial, and institutional systems. Major thrusts are efficiency, electricity generation (i.e., technical feasibility for 100% renewable potential across all islands), electricity transmission and distribution (i.e., to create a resilient, reliable and smart grid), and transportation (i.e., biofuels and electric vehicles), and also the integration of all of these into an interactive energy system.

Hawaii's critical issues for success are the formulation of winning policies and regulations, the opening of the market for renewable and energy efficiency technologies, the implementation of non-partisan clean energy legislation, private leadership and community involvement, and partnership approaches. What is needed for success are individual action, legislative action, the identification of new business models, successful regulatory change, incentives and mandates, and leadership at all levels.

Grid Integration of Wind Energy

Hawaii Energy, Environment and Sustainability, Aspects of Grid Integration of As-Available Resources⁶

Hawaii is heavily dependent on petroleum. The energy challenges for Hawaii are reducing dependence on oil while keeping electricity and fuel costs competitive, managing the environmental impact and public acceptance, maintaining reliability, and addressing greenhouse

5. Presented by William P. Parks Jr., Deputy Assistant Secretary, Power Technologies, US Department of Energy.

6. Presented by Terry Surles, Ph.D., Hawaii Natural Energy Institute, University of Hawaii at Manoa.

gas issues. Meeting these challenges requires coordination from all stakeholders. Hawaii Natural Energy Institute (HNEI)'s activities related to the issue of energy independence include the Hawaii Public Utility Commission Renewable Portfolio Standard (PUC RPS) goal evaluation, the Hawaii/New Mexico Energy Security Project, the Hawaii Renewable Energy Development Venture, and the Maui Smart Grid.

Hawaii's statutes require that 10% of delivered electricity come from renewable electric technologies by 2010, 15% by 2015, and 20% by 2020. At least 50% of these goals must be met by renewable electric energy. The other 50% may come from electrical energy displaced by other renewable energy technologies, i.e., solar hot water heaters or improvements in end-use efficiency and demand-side management. HNEI analysis of the Renewable Portfolio Standard for the Hawaii Public Utility Commission confirmed that the utilities could meet the 2010 goals.

The Hawaii/New Mexico Energy Security Project was unique in being able to address the needs of four different end-users as well as the stakeholders. The project meets DOE mission needs of transferability of analytical tools, addresses utility system planning needs with accurate and usable tools, and addresses the state Department of Business, Economic Development and Tourism (DBEDT) and PUC's initiatives. The project also provides information to commercialize clean energy products and respond to concerns of multiple businesses, the environment, and consumers and stakeholders in Hawaii.

The existing partnership activities in Hawaii that are part of the energy security project include *Kauai Energy Roadmap* (develop possible roadmap for increasing the penetration of renewable energy), *Oahu Grid (Big Wind) Study* (develop models to characterize the grid and to address wind projects that could impact the island), *Maui Grid Modernization* (deploy energy storage, generation and demand-side management technologies to reduce peak load and enable further expansion of renewable energy), *Maui Grid Study* (develop validated power systems model to address impacts of increased wind and the necessary mitigation technologies), and *Big Island Energy Roadmap* (evaluate scenarios to identify the impacts and benefits of various technology approaches to increase energy security and the penetration of renewable energy).

Given the trends in Hawaii for increased wind farm development, a renewable energy strategy consisting mainly of increased wind utilization was considered, assuming wind capacity was increased at each of the three wind farms on the Big Island. If 1 MW of wind power were added to the island, with no other changes to the system, an increase in wind power would offset fossil fuel generation and reduce emissions and the carbon footprint. However, that same scenario would result in a need for more spinning reserve. This additional spinning reserve requires burning additional oil but does not produce additional power. If wind developers are paid avoided costs, consumers could actually pay more for power.

The Pacific International Center for High Technology Research is leading the Hawaii Renewable Energy Development Venture, which is funded by DOE/EE. HNEI provides support for development of selection metrics including commercial readiness, specific technology areas, linkage to state and federal policies, and corporate qualifications. The specific technology areas focus on the utilization of indigenous renewable resources, separate categories for transportation

and electricity generation, enabling technologies for greater utilization of renewable resources, and end-use efficiency and demand response technologies.

The Maui Smart Grid Project is designed to meet federal, state and utility needs. The overarching objective is to develop and demonstrate a distributed automation system that aggregates distributed generation, energy storage, and demand response technologies in a distribution system to achieve transmission and distribution level benefits. The focus is on reducing peak demand at least 15% by using a diverse mix of distributed generation, storage, renewable energy, and demand response. Efforts are being made to provide solutions for mitigating the effects of as-available renewable energy.

Wind Power Grid Integration in New Zealand⁷

Total installed electricity capacity in New Zealand in 2008 was 9,133 MW, of which about 67% was from renewable energy. The principal renewable resources for electricity generation in New Zealand is hydro (55% of total electricity capacity), and the others include geothermal, wind, wood, and biogas. About 320 MW of installed electricity capacity or 3% of total electricity generation in New Zealand is currently from wind power. Integration of wind power into the grid is somewhat easier in New Zealand than in other countries due to the reliability of the wind resource, proximity to the grid, the availability of large amounts of rapidly switchable electricity and the existence of electricity supply, reserve and frequency keeping markets that can provide whole system support. Important New Zealand grid integration characteristics include a load that is relatively small compared to grid size, lack of external links, and load is split into two grids by a high voltage direct current or HVDC link. Grid integration challenges in New Zealand include frequency management, short term variations, generation scheduling, wind farm clustering, and formulation of standards and regulations.

Several technical solutions are employed in New Zealand for renewable energy grid integration issues. Those include improving generator technology (for voltage control at the output terminals, maintaining consistent output during grid faults, and maintaining output over a range of grid frequencies), balancing intra-generator load (primarily with hydro and geothermal), wind forecasting, energy storage, and system strengthening (up-rating hydro/stations, grid strengthening and improving fault ride-through requirements). While all of the technical solutions for minimizing and utilizing VARs are deployed in New Zealand, most grid integration problems are addressed primarily through market mechanisms. The ongoing issues in grid integration in New Zealand include (1) imperfect wind flow forecasting, (2) electricity replacement that may be at different nodes, (3) wind farm clustering, and (4) good industry standards and market rules.

Wind power integration is not a major issue in New Zealand. System analyses indicate that the current facilities for wind power integration in New Zealand would enable about 35% market penetration without the introduction of additional infrastructure.

Grid Integration of Solar Energy

7. Presented by David F. S. Natusch, Resource Development Limited, New Zealand.

Promises and Challenges of Utility Scale PV Grid Integration⁸

Large photovoltaic systems offer the promise of lower costs of electricity and also simpler control by the utility. The goal is to make these large scale systems true utility assets, but there are a number of technical and regulatory hurdles to overcome. SatCon, SunPower, and Florida Solar Energy Center (FSEC) worked together to develop the 1.5 MW grid PV system in Lanai. SunPower was the PV system designer and integrator. SatCon was the grid connected inverter manufacturer, and FSEC is a SatCon partner for the project. Lanai Sustainability Research (LSR), LLC, is the owner of the solar farm and is selling power to Maui Electric Company (MECO).

The MECO-LSR power purchase agreement (PPA) for as-available energy was signed on August 8, 2008. The PPA stipulates several site control features including curtailment control, remote-control of power factor, grid disturbance ride through, and ramp-rate limits and control. For curtailment control, the PPA stipulates that the utility provide set points in fairly continuous increments between 0-1200 kW, that plant response should be rapid without violating ramp-rates limits, and that the utility receive status indicating achievement of set point. For power factor control, the utility provides set points between 0.95 lagging to 0.98 leading, the utility receives status indicating achievement of set points, and the PV plant produces and consumes reactive power at utility command. For ramp-rate limiting, plant output fluctuations need to be limited to 6 kW/s during beginning/end of day and startup and shutdown periods, and plant output fluctuations needed to be limited to 40-60 kW/s at other times.

The presentation covered challenges in integration, from communicating with Supervisory Control and Data Acquisition (SCADA) systems, through transient fault ride-thru requirements in weak grids, and the stabilizing potential of inverters with some moderate amount of storage. The principal challenge of developing a 1.5 MW grid connected PV system in Lanai stemmed from the fact that the total nominal load in Lanai is only 4 MW. That load was previously met by two 2.2 MW diesel generators with six 1 MW diesel locomotive “standby” generators.

Several PV site controller challenges were addressed in the Lanai system. These included the fact that curtailment was measured at the point of interconnection but control was achieved at the inverters. Power factor was also measured at the point of interconnection. One big challenge was in communication latency. This challenge can occur at the inverter, which requires time to process commands and then act. Another source of latency was created by the communication network itself and the protocol employed.

The control features are new to PV plants and there is much development work to be done, as well as many opportunities. The opportunities for improvement include the optimization of control techniques, the normalization of the utility human-machine interface (HMI), integration with storage, ancillary services like voltage support, open loop versus closed loop control, remote restart and reclosing, and parallels to smart grid.

8. Presented by Leo Casey, SatCon, Leo.Casey@SatCon.com; Robert Johnson, SunPower, Robert.Johnson@sunpowercorp.com; and Bob Reedy, Florida Solar Energy Center, reedy@fsec.ucf.edu.

NEDO Research Related to Large-scale PV-related Grid-connection Projects⁹

The New Energy and Industrial Technology Development Organization (NEDO) is Japan's largest public R&D management organization for promoting the development of advanced industrial, environmental, new energy and energy efficiency technologies. An important NEDO objective is resolving problems that arise when fluctuating renewable energy resources, such as wind and solar power, are connected to power grids. NEDO has promoted a number of grid-connection-related demonstration projects, including *Demonstrative Project on Grid-interconnection of Clustered Photovoltaic Power Generation Systems* (FY2002-2007) and *Verification of Grid Stabilization with Large-scale PV Power Generation Systems* (FY2006-2010).

For *Demonstrative Project on Grid-interconnection of Clustered Photovoltaic Power Generation Systems*, photovoltaic (PV) systems were installed on the rooftops of 550 homes in Ota City, Japan. The objectives of the project were to develop technology to eliminate output restrictions on PV systems connected to grids, to develop a method to detect unintentional islanding, and to develop applied simulation technologies. Battery systems were installed at each residence in order to control voltage on distribution lines. Through this project, researchers gained important data on actual residential demand, PV output and battery storage operation, and were able to summarize the feasibility of installing individual battery systems. Researchers also discovered the potential for interference among the equipment used to prevent islanding. Using the results of this project, a new islanding detection system for clustered PV systems that is not prone to interference is being developed and tested and will be installed at the project site.

Under the *Verification of Grid Stabilization with Large-scale PV Power Generation Systems* project, grid connection technologies for megawatt-scale PV solar systems are being studied at two sites in Japan (Wakkanai and Hokuto), under the assumption that megawatt-scale installations may become increasingly common and that these installations may affect voltages and frequencies on utility grid systems. The purpose of this project is to demonstrate power storage and power conditioning technology, to test a wide variety of PV cells from various manufacturers, to develop and demonstrate harmonics countermeasures, and to develop simulation methods.

In addition, a pre-feasibility study of future network technologies was conducted in Japan, in anticipation of the widespread installation of renewable energy systems. Through this study, the potential for the rapid penetration of PV systems and future problems, such as the challenge of controlling voltages, the instability of the main grid and the imbalance of demand and supply, which grid systems will need to address in the future, were identified.

The US DOE Solar Energy Grid Integration Systems (SEGIS) Program¹⁰

9. Presented by Hirofumi Nakama, Project Coordinator, New Energy Technology Development Department, New Energy and Industrial Technology Development Organization.

SEGIS is a project under US DOE's Systems Integration Program and Solar America Initiative (SAI). SEGIS is designed to fill R&D gaps in SAI Technology Pathways Partnership (TPP) agreements, to support DOE Solar Energy Technology Program areas (Smart Grids, Energy Storage/Management) and to prepare for high-penetration PV in the context of the future "Smart" utility grid. The SEGIS vision is to enable highly integrated, innovative, advanced inverters, controllers, critical balance of system (BOS) concepts and energy management for residential and commercial PV applications. SEGIS R&D focuses significantly on advanced inverters, controllers and energy management systems that maximize value to utilities and consumers. The SEGIS R&D covers PV systems for high-value residential and commercial applications (100 W-250 kW), PV systems using advanced energy management, building/structure PV systems and hybrid/micro-grid applications that utilize energy storage. SEGIS R&D does not include the development of PV cell/module or energy storage technology.¹¹

The SEGIS request for proposals (RFP) provides for three-year and three-stage cost-shared efforts. Stage 1 is for proof of concept and market analysis (for 9 months, 20% cost share with \$250,000 maximum). Stage 2 is for prototype development (for 1 year, 20% cost share with \$3million maximum). Stage 3 is for the path toward commercialization (for 1 year, 50% cost share with \$3 million maximum). Twenty-six proposals were received, and 12 proposals were selected for stage 1. The contract awards are divided into 4 groups—including (1) less than 1 kW representing micro-inverters (all are unique topologies, and all are integrated with PV modules); (2) between 1-10 kW representing residential systems; (3) between 10-100 kW representing commercial systems; and (4) more than 100 kW representing commercial or utility systems. The commonalities of the SEGIS contracts are that all contracts include inverter design or modification, controller design, energy management systems (EMS), system integration, communications, and utility support. Proposed developments are likely to require changes in interconnection or other standards.

SEGIS near term spin-off applications include future Solar America Cities Programs, critical state supported demonstration generation programs, joint utility/industry programs to meet renewable mandates, intermittency mitigation with energy storage, residential PV developments, PIHV applications, and micro-grid installations.

Energy Storage and Renewable Energy

A Case for Energy Storage as Part of Hawaii's Power Generation Plan¹²

The movement to expand the use and penetration of renewable energy technologies as options for cleaner energy sources directly involves storage. Without a cogent discussion of energy

10. Presented by Abraham Ellis (aellis@sandia.gov) and Ward Bower (wibower@sandia.gov), Sandia National Laboratories.

11. SEGIS concept paper can be found at www.sandia.gov/SAI/files/SEGIS%20Concept%20Paper-071025.pdf.

12. Dan Borneo, Sandia National Laboratories.

storage as part of the resource planning, both the end-users and electric utilities are faced with questions about reliability and dispatchability. In simple terms, the variability that is associated with wind and photovoltaic (PV) energy can mean that electric power is available only when the wind is blowing or the sun is shining. Energy storage allows renewable generating sources to be dispatchable or available when needed. For island systems, a large penetration of a variable source power such as wind energy could introduce electrical instabilities that must be managed (usually through the use of storage). Currently the grid functions as the storage medium for wind and PV. However, this approach requires that generators be kept running either in stand-by mode or at reduced loads. Neither is an efficient means to operate a power generator. Both methods increase maintenance, CO₂ emissions, and fuel costs.

Energy Storage and Renewable Energy¹³

Renewable energy resources such as photovoltaic, wind and wave energy are intermittent, diurnal, seasonal and vary randomly. Energy storage systems smooth renewable energy output, extend dispatch capacity and capture spillage. Energy storage technologies include pumped storage, battery energy storage, flywheels, and super conducting magnetic energy storage (SMES).

Battery Storage Applications for Integration of Renewable Energy¹⁴

Stationary batteries and other energy storage technologies for power grids have been a focus in Japan since the 1970s, although the application for these technologies has evolved. Based on forecasts for wind and PV installations, it is estimated that Japan will require approximately 93,700 MW of storage by the year 2030 to offset the negative impacts of fluctuating power from PV systems and wind turbines. In response, the New Energy and Industrial Technology Development Organization (NEDO) has been focusing on several energy storage applications for renewable energy and has promoted several demonstration projects since 2000.

In fiscal year 2007, four major demonstration projects, *Demonstrative Project of Regional Power Grids with Various New Energies* (FY2003-2007), *Demonstrative Project on Grid-interconnection of Clustered Photovoltaic Power Generation Systems* (FY2002-2007), *Wind Power Stabilization Technology Development Project* (FY2003-2007) and *Demonstrative Project on New Power Network Systems* FY2004-FY2007, were completed. Another demonstration project, *Verification of Grid Stabilization with Large-scale PV Power Generation Systems* (FY2006-2010), is ongoing.

NEDO has approached the grid connection issue from several angles: 1) Avoiding voltage increases on distributions lines, 2) Reducing output fluctuations from renewable energy, 3) Achieving scheduled output from renewable energy systems, and 4) Balancing demand and supply on a micro-grid. Research results to date have shown that battery storage can reduce

13. Presented by Abbas Akhil, Energy Storage and Distributed Generation, Sandia National Laboratories, aaakhil@sandia.gov.

14. Presented by Dr. Satoshi Morozumi, Director for Grid-connected Power Technology, New Energy Technology Development Department, New Energy and Industrial Technology Development Organization.

output fluctuations from renewable energy, that present battery costs need to be cut in half, and that although difficult, maintaining the efficiency of inverters is critical for renewable power applications.

In another ongoing project, *Development of an Electric Energy Storage System from Grid-connection with New Energy Resources* (FY2006-2010), NEDO seeks to establish (a) technologies for a megawatt-scale storage system, (b) module level technologies to reduce costs and expand capacity, (c) low cost, next-generation storage technologies to be commercialized by 2030, and (d) conduct fundamental research to evaluate safety, economic feasibility and lifecycle.

Grid Operations and Management

Forest City Projects¹⁵

Forest City Enterprises, Inc., was established in 1920. Forest City is a major property developer that integrates sustainable energy systems into an overall development strategy. The company is dedicated to strategically balancing environmental resources, economic objectives, and social systems.

Forest City is currently implementing a number of public-private venture (PPV) projects in Hawaii. The projects include integrating solar thermal and solar PV systems into Navy and Marine housing blocks. Utility costs were about 50% of all non-controllable expenses that Forest City had to pay. By integrating solar energy into the projects, the company was able to lower utility costs significantly. Forest City is also working on a State of Hawaii project at Kamakana Village at Keahuolu on the Big Island that had a potential \$8 million shortfall. To erase this shortfall, Forest City is examining the creation of an income stream of about \$500,000 from a PV farm that would erase the shortfall.

In the Navy and Marine projects, the challenge was to make “non-controllable expenses” a misnomer. The effort in the State of Hawaii project was to build affordable sustainable housing in a challenging environment. By implementing sustainable design and energy generating facilities, the projects could help improve the quality of life for residents and generate needed income streams.

Modeling and Simulation

The Particularity of the Power Network Incorporating with the Aggregation of Distributed PV Systems¹⁶

Electricity derived from solar photovoltaic installations is not a niche energy source: it can clearly make a major contribution to energy supplies in the 21st century portfolio. Because of

15. Presented by Jon Wallenstrom and William Boudra, Forest City Enterprises, Inc.

16. Presented by Dr. Kosuke Kurokawa, Professor, Tokyo Institute of Technology.

their significance for urban communities, residential PV rooftop installations are the first option. Japan developed a long-term photovoltaic research and development roadmap called “PV2030” in June 2004. Its accelerated scenario assumes the mass deployment of 100 GW of aggregated PV systems will supply 10% of Japan’s electricity by the year 2030.

Residential rooftop installations will comprise approximately one-half of this capacity. Under this scenario, PV penetration will reach 100% in the majority of urban areas and might become less harmonized with the conventional power grid approach due to expected frequent high-level reversal power flows from PV systems to upstream grids. Improvements to distribution grids are required to integrate massive aggregated residential PV system installations and must be included in urban planning. Among the improvements required for higher penetration will be modifications of grid operations for balancing demand/supply and the deregulation of power systems.

“Autonomy-enhanced PV clusters” (AE-PVC) is a novel approach to lessen the impact of aggregated PV installations on existing power grids by adding power electronics and energy storage. Early results have already been obtained, including conceptual definitions of autonomy-enhanced, community-based clustered PV systems. Bulk PV systems will require substantial social support to move forward in the 21st century. Changes to power grids should be carried out under the principle of minimizing social costs and gaining public acceptance to spread the burden of these costs among society as a whole.

Renewable Energy Interconnection and Storage—Technical Aspects¹⁷

Climate change concerns, renewable portfolio standards, incentives, and accelerated cost reduction have driven steep growth in US renewable energy system installations. Concerns with integrating renewables are penetration, infrastructure capacity (lack of transmission capacity from stranded renewable resource locations), variable and uncertain generation, and technical concerns. Penetration is affected by utilities’ existing generation mix regulating capabilities, load characteristics, resource availability, and correlations between system load and resources. Increasing the penetration of renewable energy systems imposes additional systems costs due to variability and uncertainty. Costs are moderate with penetration up to 20-30%, depending on balancing authority and market structure. Solutions to variable and uncertain generation are spatial diversity of the resource, flexible conventional generation, grid operations and control areas, limited curtailment for extreme events, load management, and the use of energy storage at high penetrations. The major values of energy storage include timeshifting of energy and capacity, regulating reserves, and reducing power plant cycling. Technical concerns are real, but solvable. Most technical concerns at the bulk level have been solved with modern wind turbines and grid codes. Technical concerns at the distribution level have been identified, but small renewables have not been fully integrated into planning and operations.

Several large wind integration studies are available. Those include California Intermittency Analysis¹⁸, Minnesota State 20% Wind Integration Study¹⁹, Northwest Wind Integration Action

17. Presented by Ben Kroposki, PE, National Renewable Energy Laboratory.

18. www.energy.ca.gov/pier/notices/

Plan²⁰, New York ISO and NYSERDA²¹, MISO 20-25% wind study, and Western Wind Integration Study.

Energy storage options include pumped hydro, CAES, batteries (lead acid, NaS, VRB, lithium ion, etc.), super caps, flywheels, hydrogen, PHEV/V2G, thermal storage, and natural gas. No storage need is found in wind studies looking at up to 20-30%. Most storage is not currently economically feasible.

Individuals have to contact their utility and obtain an “interconnection agreement” before connecting distributed renewables to utility lines. Often, a simple, standard agreement is available for small renewable energy systems. The United States Energy Policy Act of 2005 or EPACT 2005 offers interconnection support. It requires utilities to consider interconnection services to its customers (on-site generation connected to distribution facilities). According to EPACT 2005, interconnection services shall be offered based upon IEEE 1547, and agreements and procedures will be established, promoting current best practices of interconnection, including practices stipulated in state regulatory model codes.

The needs for distributed renewables include distributed renewable interconnection technologies with advanced functionality, the integration of renewable energy with dispatchable loads and storage, electric power systems technologies, controls and operations that enable a high penetration of distributed renewable energy systems, and models for renewable energy systems to be included as planning and analysis tools.

Renewable Energy Grids Over Time

Japanese Policies Related to New and Renewable Energy & Grid Integration²²

Led by the Ministry of Economy, Trade and Industry (METI), Japan has implemented a variety of policy measures aimed at short-, medium- and long-term new and renewable energy targets, starting with the “Sunshine Project” in 1974. One component of this policy was providing subsidies for residential photovoltaic (PV) system installations from 1993 to 2005. This aspect, allowed the creation of a domestic PV market, thereby facilitating a decrease in PV system costs. Last year, Japan’s cabinet approved the “Action Plan for Achieving a Low-Carbon Society,” which calls for a ten-fold increase in PV capacity by 2020, a 40-fold increase by 2030, and a 50% reduction in solar PV power generation system costs within three to five years. To jump-start domestic installations, subsidies of approximately \$700 per kW for residential systems, one-

19. www.puc.state.mn.us/docs/index.htm

20. www.nwcouncil.org/energy/Wind/Default.asp

21. www.nyserda.org/publications/wind_integration_report.pdf

22. Presented by Takashi Kawabata, Technical Official, New and Renewable Energy Division, Energy Conservation and Renewable Energy Department, Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry.

third for commercial installations and one-half for public sector installations are available. Incentives were also instituted under Japan's Renewables Portfolio Standards Law (RPS) to expand the use of PV. Electricity production from renewable energy sources was targeted at 12.2 billion kWh for FY2010, increasing to 16 billion kWh by FY2014, up from actual output of 6.51 billion kWh in FY2006.

According to the Chairman of the Federation of Electric Power Companies of Japan (FEPC), the interconnection of up to 5 million kW of wind power (3 times present levels) and 10 million kW of solar power (7 times present levels) might be possible in Japan. However, the rapid and widespread installation of renewable energy systems may have a negative impact on electricity grids, including the destabilization of voltages and/or frequencies and will require a major renovation of the power system infrastructure. Because Japanese grid capacity is rather small compared with Europe or the US, measures to stabilize the grids and address the cost burden are now under discussion.

Three technological options for residential PV systems are currently being considered. The first would involve installing battery systems in tandem with each residential system. Under the second option, centralized battery systems within transmission and/or distribution networks would be installed. The third, and least expensive option, would involve temporarily disconnecting PV systems from the grid when technical issues arise.

Collaboration on Renewable Energy Grid Issues

Renewable Systems Interconnection Study²³

To facilitate a high penetration of renewable distributed electric generation, US DOE launched the Renewable Systems Interconnection (RSI) study during the spring of 2007. The study addressed the technical and analytical challenges that must be addressed to enable high penetration levels of distributed renewable energy technologies. This RSI study addresses grid-integration issues as a necessary prerequisite for the long-term viability of the distributed renewable energy industry, in general, and the distributed PV industry, in particular.

The RSI focuses on six areas: Distributed PV System Technology Development, Advanced Distribution Systems, System Level Test and Demonstration, Distributed Renewable Energy System Analysis, Solar Resource Assessment, and Codes, Standards and Regulatory Implementation. Fourteen reports are nearing completion.

Lanai—A Source of Renewable Energy for Hawaii²⁴

Hawaii needs energy resource security and energy price stability. Hawaii's dependence on imported oil is the highest in the US. Over 90% of fuel for energy in Hawaii comes from overseas. Hawaii's average electricity rate was \$0.13 per kWh in 2002, and \$0.28 per kWh in

23. Presented by Juan Torres, Manager, Energy System Analysis, Sandia National Laboratories.

24. Presented by Christopher Lovvorn, Castle & Cooke Resorts, LLC; clovvorn@castlecooke.com.

2008. The average monthly electric cost in Hawaii in 2008 was \$280. In October 2008, the State and Hawaiian Electric Company (HECO) committed to the following activities: the integration of 1100 MW of additional renewable energy already identified on HECO grids (700 MW to be implemented within 5 years); the construction of undersea cables connecting Maui, Molokai, and Lanai into one grid to allow the integration of an additional 400 MW of renewable wind power generated in Maui County for transmission to Oahu; a requirement to produce 40% of electric power from renewable sources by 2030 (doubling the current renewable portfolio standard); the integration of up to 400 MW of wind power into HECO's renewable energy commitments; and the rapid development of as much renewable energy as possible.

Castle & Cooke is leading the development of renewable energy on Lanai. The 1.5 MW La Ola Solar Farm—Hawaii's largest solar farm—has been in service on Lanai since December 2008. It generates 3,000 MWh of electricity per year, which is about 30% of Lanai's daytime peak demand or 10% of Lanai's annual demand. The power generated from La Ola Solar Farm equals the use of 5,000 barrels of oil or 237,000 gallons of gasoline and eliminates 2,300 tons of carbon dioxide emissions annually.

In addition to the solar farm, Castle & Cooke is taking action in assessing Lanai's wind energy potential. A feasibility study on wind power in Lanai was conducted in March 2007. The first meteorological tower or "met tower" was installed in August 2007. An additional five towers were installed in February 2008. Castle & Cooke is also working with the State on environmental impact studies and permitting under Act 207. Avian studies, cultural surveys, and other biological and botany surveys are ongoing.

There are several advantages to developing a wind farm on Lanai. Wind is the most cost effective renewable energy at a utility scale. Further, having one large-scale project makes it more efficient since less development support effort is needed than with numerous smaller projects. With one large-scale wind project, Hawaii can take a major step towards its goals of a 70% clean energy economy and create momentum to get it done. In addition, the land which would be used is primarily in remote areas on Lanai and controlled by one landowner making it easier to develop the project.

12 Jan 2009 Monday

6:00pm Registration
6pm-8pm Meet & Greet Reception

13 Jan 2009 Tuesday

7:30 am On-site Registration
7:30 Breakfast
9:00 Welcome Address – Chris Lovvorn, Castle & Cooke
9:15 Introductions, Workshop Objectives - Juan Torres, SNL
9:20 Greetings – State of Hawaii: Ted Liu, DBEDT
9:25 Greetings – APEC: Cary Bloyd, ANL
9:30 Presentation/Recognition of Speakers – Ken Johnson, NEDO
9:45-10:15 DOE Solar Energies Technologies Program – Dan Ton, DOE
10:30-11am Keynote – Bill Parks, Hawaii Clean Energy Initiative

11-12:30 Grid Integration of Wind Energy

11:00 Terry Surles, Hawaii Natural Energy Institute
11:40 David Natusch, APEC Energy Business Network

12:30 Lunch**2:00-3:30 Grid Integration of Solar Energy**

2:00 Abe Ellis (Presenting for Ward Bower), SNL
2:30 Hirofumi Nakama, NEDO
3:00 Leo Casey, SatCon Technology Corporation
Bob Reedy, FSEC
Robert Johnson, SunPower Corporation

3:30 Snack/Refreshment Break**4:00-5:30 Energy Storage & Renewable Energy**

4:00 Satoshi Morozumi, NEDO
4:40 Abbas Akhil, SNL

6:00 *Dinner Greetings by Sponsors: Castle & Cooke and Forest City*

14 Jan 2009 Wednesday

7:30 am On-site Registration

7:30 Breakfast

8:45 Review & Preview

9:00-10:30 Grid Operations & Management / Facilitated Discussion

9:00 Presentation by Jon Wallenstrom & Will Boudra of Forest City

9:30 Round Table Discussion of Challenges, Opportunities

10:00 Question & Answer Session

10:30 Refreshment Break

11-12:30 Modeling and Simulation Presentations

11:00 Kosuke Kurokawa, Tokyo Institute of Technology

11:40 Ben Kroposki, NREL

12:30 Lunch

2:00-3:30 Facilitated Discussion/Renewable Energy Grids over Time

2:00-2:40 Kosuke Kurokawa (Part II), Tokyo Institute of Technology

3:00-3:40 Takashi Kawabata, METI

3:45 Round Table Discussion of Challenges, Opportunities

4:00-5:30 Facilitated Discussion: Collaboration on Renewable Energy Grid Issues

4:00 Juan J. Torres, SNL

4:30 Round Table Discussion of Challenges, Opportunities

5:00 Question & Answer Session

15 Jan 2009 Thursday

10:00-12:15 Tour of Solar Farm on Lāna'i

10:00 Bus to Pick up Invited Guests

10:30 Arrival at Site

10:45 Tour w/ Chris Lovvorn (Castle & Cooke)
and Duke Shaffer (SunPower)

11:30 Depart Site

12:15 Return to Four Seasons Resort

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